Standard for Constructed Stormwater Wetlands

Definition

Constructed stormwater wetlands are wetland systems designed to maximize the removal of pollutants from stormwater runoff through wetland vegetation uptake, retention and settling. Constructed stormwater wetlands temporarily store runoff in shallow pools that support conditions suitable for the growth of wetland plants. Like detention basins and wet ponds, constructed stormwater wetlands may be used in connection with other BMP components, such as sediment forebays and micropools.

Purpose

- To allow for the settlement of particulate pollutants.
- To allow for the biological uptake of pollutants by wetland plants.
- To reduce peak discharges and reduce occurrence of downstream flooding. [Note: Detention storage capacity must be part of the design in order to meet this goal.]

Advantages

- Relatively low maintenance costs.
- Has high pollutant removal efficiency.
- Can enhance the aesthetics of a site and provide recreational benefits.

Disadvantages

- Depending upon design, larger land requirements than for other BMPs.
- Until vegetation is well established, pollutant removal efficiencies may belower than anticipated.
- Relatively high construction costs in comparison to other BMPs.
- Seasonal variations in treatment and pollutant removal efficiencies

Conditions Where Practice Applies

Similar to wet ponds, constructed stormwater wetlands require relatively large contributing drainage areas and/or dry weather base flow. Minimum contributing drainage areas should be at least ten acres, although pocket type wetlands may appropriate for smaller sites if sufficient ground water flow is available.

Constructed stormwater wetlands should not be located within natural wetland areas. These engineered wetlands differ from wetlands constructed for compensatory storage purposes and wetlands created for restoration. Typically, constructed stormwater wetlands will not have the full range of ecological functions of natural wetlands. Constructed stormwater wetlands are designed specifically for flood control and water quality purposes.

Design Criteria

1 Design Approach

The use of constructed stormwater wetlands is limited by a number of site constraints, including soils types, depth to groundwater, contributing drainage area, and available land area at site. Where land area is not a limiting factor, the use of several wetland design types is possible; where land area is limited, the use of the pocket type wetland design may be possible.

Medium-fine texture soils (such as loams and silt loams) are best to establish vegetation, retain surface water, permit groundwater discharge, and capture pollutants. At sites where infiltration is too rapid to sustain permanent soil saturation, an impermeable liner may be required. Where the potential for groundwater contamination is high, such as runoff from sites with a high potential pollutant load, the use of liners should be required. At sites where bedrock is close to the surface, high excavation costs may make constructed stormwater wetlands infeasible.

A “pondscaping plan” should be developed for each stormwater wetland. This plan should include hydrological calculations (or water budget), a wetland design and configuration, elevations and grades, a site/soil analysis, and estimated depth zones. The plan should also contain the location, quantity, and propagation methods for the stormwater wetland plants. Site preparation requirements, maintenance requirements and a maintenance schedule are also necessary components of the plan.

The water budget should demonstrate that there will be a continuous supply of water to sustain the stormwater wetland. The water budget should be developed during site selection and checked after preliminary site design. Drying periods of longer than two months have been shown to adversely effect plant community richness, so the water balance should confirm that drying will not exceed two months.

The recommended minimum design criteria for constructed stormwater wetlands are listed in on Table 1.

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Design Criteria

- Establishment and maintenance of the wetland vegetation is an important consideration when planning a stormwater wetland. Horner et al. (1994) compiled the following list of recommendations for creating wetlands:

- In selecting plants, consider the prospects for success more than the specific selection of native species should avoid those that invade vigorously

Table 1. Recommended Design Criteria For Stormwater Wetlands

Design Criteria	Shallow Marsh	Pond / Wetland	ED Wetland	Pocket Wetland
Wetlands/Waters Ratio	0.2	0.01	0.01	0.01 (target)
Minimum Drainage Area (acres)	25	25	10	1 to 10
Length to width Ratio (minimum)	1:1	1:1	1:1	1:1 (target)
Extended Detention	No	No	Yes	No
Allocation of Treatment Volume (pool/marsh ED)	30/70/0	70/30/0	20/35/45	20/80/0
Allocation of surface area (depth to height)	20/40/40	45/25/30	20/35/45	10/40/50
Cleanout Frequency (years)	2 to 5	10	2 to 5	
Forebay	Required	No	Required	Optional
Micropool	Required	Required	Required	Optional
Outlet Configuration	Reverse-Slope pipe Or hooded Broad crest weir	Reserse-Slope pipe Or hooded Broad crest weir	Reserse-Slope pipe Or hooded Broad crest weir	Hooded broad crest weir

- Since diversification will occur naturally, use a minimum of species adaptable
- Give priority to perennial species that establish rapidly.
- Select species adaptable to the broadest ranges of depth, frequency and duration of inundation (hydroperiod).

- Match site conditions to the environmental requirements of plant selections.
- Take into account hydroperiod and light conditions.
- Give priority to species that have already been used successfully in constructed stormwater wetlands and that are commercially available.
- Avoid using only species that are foraged by the wildlife expected on site.
- Establishment of woody species should follow herbaceous species.
- Add vegetation that will achieve other objectives, in addition to pollution control.
- Mono-culture planting should be avoided due to increased risk of loss from pests and disease.
- The surface to approximately 10 inches, where as Bulrush has a deeper root zone, up to 18 inches.
- When possible field collected plants should be used in lieu of nursery plants. Plants collected from the field have already adapted and are acclimated to the region. These plants generally require less care than greenhouse plants. If nursery plants are used they should be obtained locally, or from an area with similar climatic conditions as the ecoregion of the constructed wetland.
- Alternating plant species with varying root depths have a greater opportunity of pollutant removal. For instance cattail have a and well established shallow root development and subsequently will remove pollutants more effectively from just below

In selecting plants, consider the prospects for success more than the specific selection of native species should avoid those that invade vigorously

The plant community will develop best when the soils are enriched with plant roots, rhizomes, and seed banks. Use of “wetlands mulch” enhances the diversity of the plant community and speeds establishment. Wetlands mulch is hydric soil that contains vegetative plant material. This mulch can be obtained where wetlands soils are removed during dredging, maintenance of highway ditches, swales, sedimentation ponds, retention/detention ponds, clogged infiltration basins, or from natural wetlands that are scheduled to be filled under permit. Wetland soils are also available commercially. The upper 6 inches of donor soil should be obtained at the end of the growing season, and kept moist until installation

Drawbacks to using constructed stormwater wetlands mulch are its unpredictable content, however limited donor removal has been compiled. Stormwater wetland vegetation development can also be enhanced through the natural recruitment of species from nearby wetland sites. However, transplanting wetland vegetation is still the most reliable method of propagating stormwater wetland vegetation, and it provides cover quickly. Plants are commercially available through wetland plant nurseries.

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2. Design Variations

There are four basic constructed stormwater wetland design types:

A. Shallow marsh systems - Figure 1.

Most shallow marsh systems consist of pools ranging from 6 to 18 inches during normal conditions. Shallow marshes may be configured with different low marsh and high marsh areas, which are referred to as cells. Shallow marshes are designed with sinuous pathways to increase retention time and contact area. Shallow marshes may require larger contributing drainage areas than other systems, as runoff volumes are stored primarily within the marshes, not in deeper pools where flow may be regulated and controlled over longer periods of time the system should have a base flow, or ground water supply, to support emergent plants.

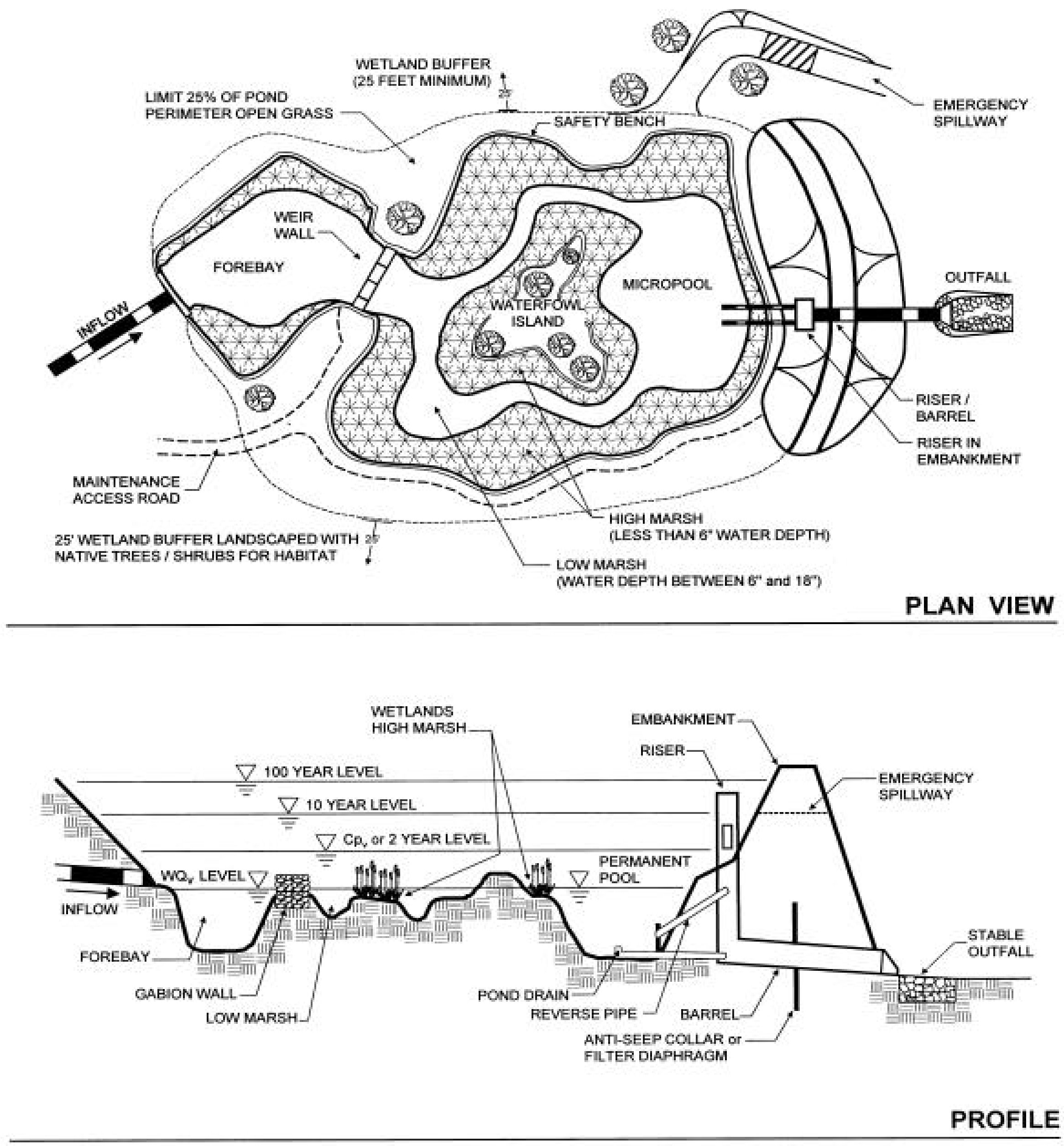
Extended detention wetlands - Figure 2.

Extended detention wetlands provide a greater degree of downstream channel protection. These systems require less space than the shallow marsh systems, since temporary vertical storage is substituted for shallow marsh storage. The additional vertical storage area also provides extra runoff detention above the normal elevations. Water levels in the extended detention wetlands may increase by as much as three feet after a storm event and return gradually to normal within 24 hours of the rain event. The growing area in extended detention wetlands expands from the normal pool elevation to the maximum surface water elevation. Wetlands plants that tolerate intermittent flooding and dry periods should be selected for the extended detention area above the shallow marsh elevations

Pond/wetland systems - Figure 3.

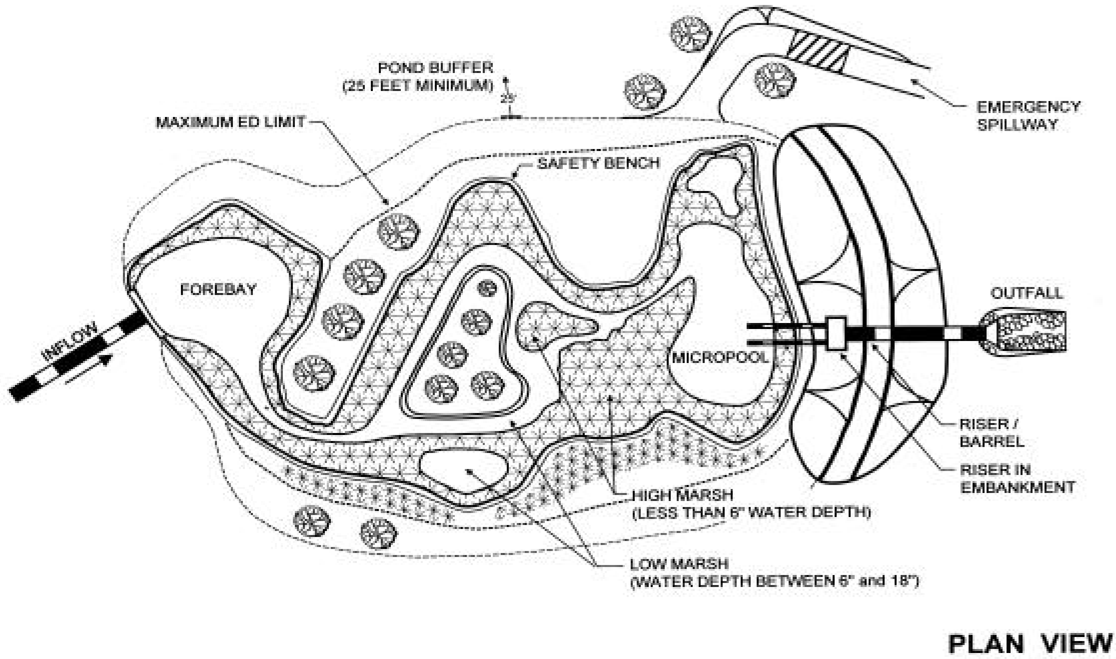
Multiple cell systems, such as pond/wetland systems, utilize at least one pond component in conjunction with a shallow marsh component. The first cell is typically the wet pond which provides for particulate pollutant removal. The wet pond is also used to reduce the velocity of the runoff entering the system. The shallow marsh provides additional treatment of the runoff, particularly for soluble pollutants. These systems require less space than the shallow marsh systems and generally achieve a higher pollutant removal rate than other constructed stormwater wetland systems.

Figure 1. Example of Shallow Marsh Wetland



Shallow wetlands provide WQ_v in a shallow pool that has a large surface area.

Figure 2. Example of Extended Detention Shallow Wetland



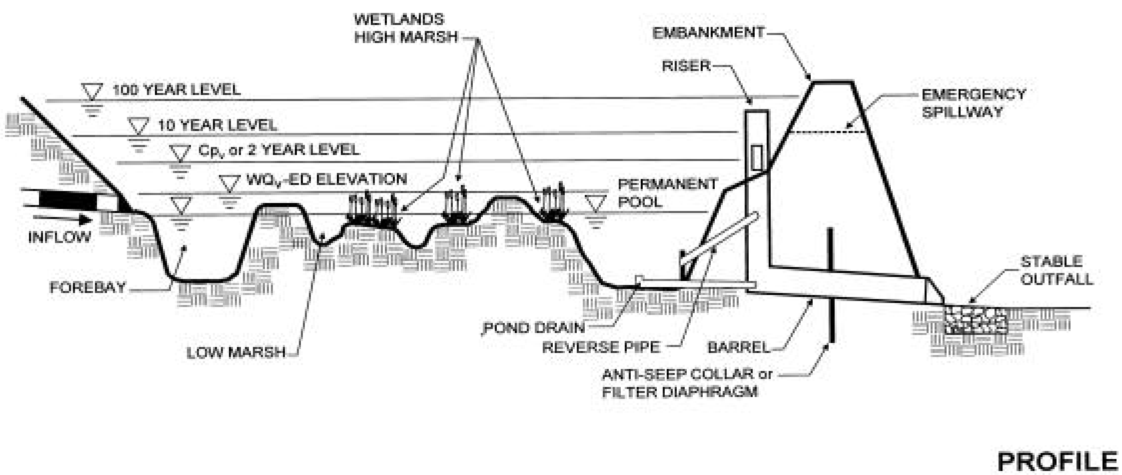


Figure 3. Example of a Pond/ Wetland System

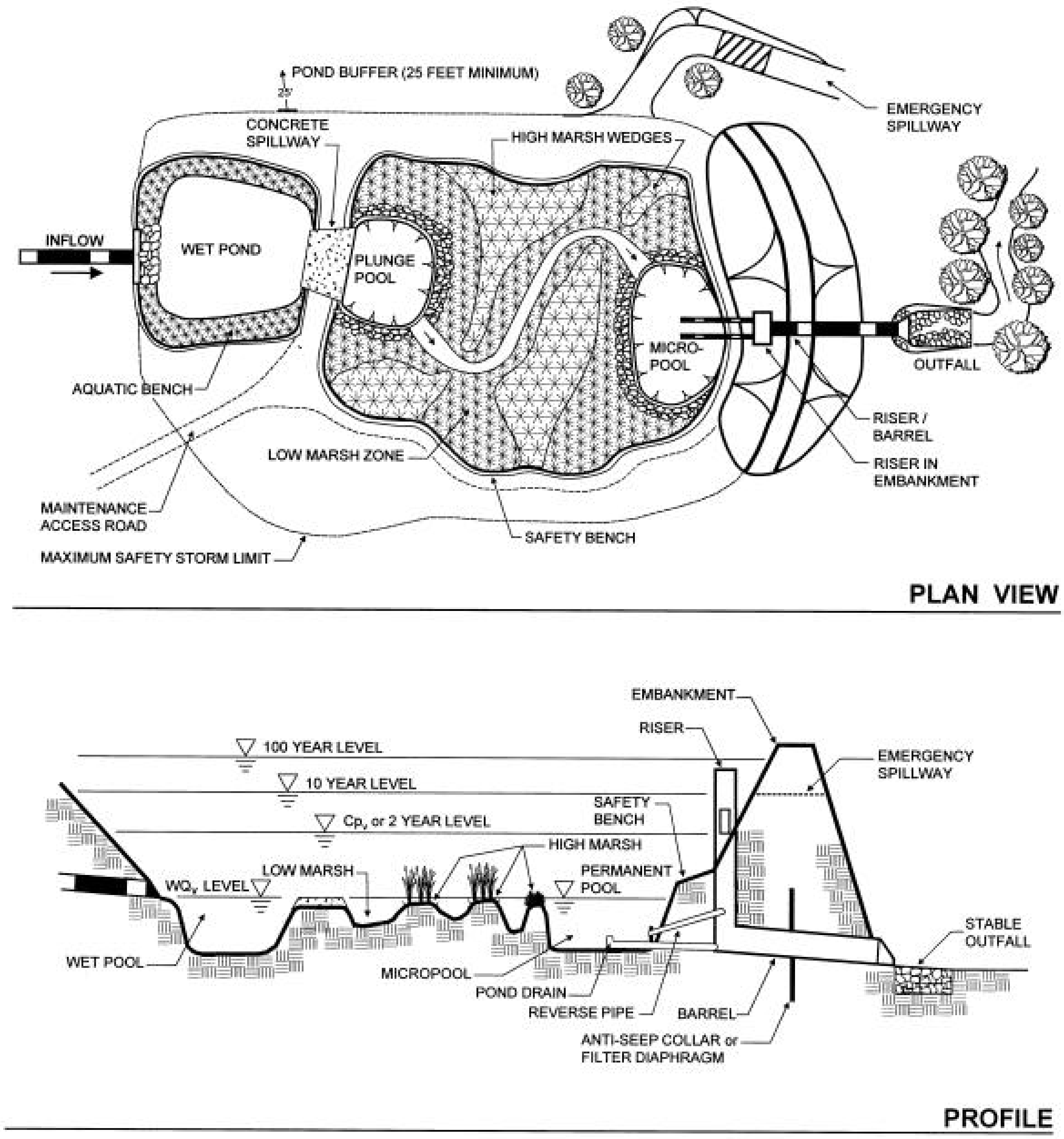
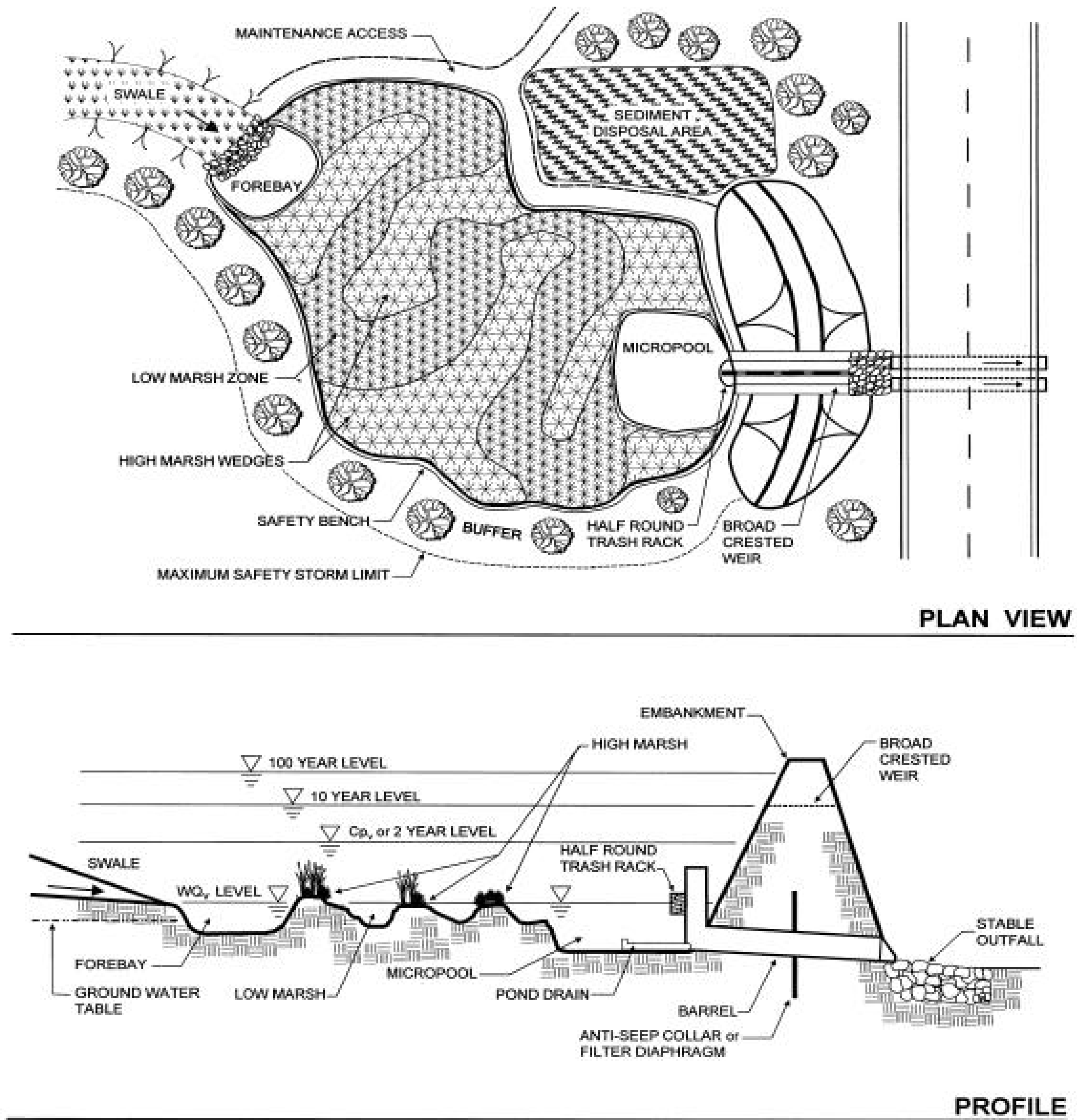


Figure 4. Example of a Pocket Wetland



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Pocket wetlands – Figure 4.

These systems may be utilized for smaller sites of one to ten acres. To maintain adequate water levels, pocket wetlands are generally excavated down to the groundwater table. Pocket wetlands which are supported exclusively by stormwater runoff generally will have difficulty maintaining marsh vegetation due to extended periods of drought.

In urban settings, natural wetlands can be altered by increases in runoff volume and rates resulting from upstream development. The existing functions and structure of the natural wetland can be altered severely when runoff becomes a major component of the natural wetland hydrological regime (or water balance). Ultimately, natural wetlands that have been altered by runoff function more like constructed stormwater wetlands systems than natural systems. One of the primary goals of comprehensive stormwater management is to protect natural wetlands from the impacts of development and increases in runoff.

3. Design

Constructed stormwater wetlands can be constructed on-line, to control the runoff volumes from design storms, in conjunction with off-line runoff quality control components.The off-line design requires two pond components and adds to stormwater system costs. Constructed stormwater wetlands may also be designed as on-line systems with a permanent pool area for treatment and a storage area for peak runoff rate control. See the following reference for complete design references: Design of stormwater wetland systems. 1992. Schueler. MWCOG Information Center.

Schueler (1992) cites the following basic stormwater wetland design sizing criteria to follow to for optimum pollutant removal. These stormwater wetland design criteria and additional considerations are summarized in *Table 1.*

- Size for the prescribed water quality treatment volume.

- Have a minimum surface area in relation to the contributing watershed area. The reliability of pollutant removal tends to increase as the stormwater wetland to watershed ratio increases, although this relationship is not always consistent. The ratios of stormwater wetland to watershed listed in *Table 1* may be reduced when it can be demonstrated that the internal flowpath and microtopography in the stormwater wetland will increase the storage area to volume ratio.

- Design the constructed stormwater wetlands with the recommended proportion of "depth zones." Each of the four stormwater wetland designs

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has depth zone allocations which are given as a percentage of the stormwater wetland surface area. Target allocations for the four stormwater wetland designs are listed in the following table.

Table 2. Recommended Design Criteria for Stormwater Wetland Designs

Target Allocations	**Shallow Marsh**	**Pond/Wetland**	**ED Wetland**	**Pocket Wetland**
<u>% of Surface Area</u>				
Forebay	5	0	5	0
Micropool	5	5	5	0
Deepwater	5	40	0	5
Low Marsh	40	25	40	
High Marsh	40	25	40	40
Semi-wet	5	5	10	5
<u>% of treatment Volume</u>				
Forebay	10	0	10	0
Micropool	10	10	10	0
Deepwater	10	60	--	20
Low Marsh	45	20	20	55
High Marsh	25	10	10	25
Semi-wet	0	0	50	0

The four basic depth zones of stormwater wetlands are as follows:

Deepwater zone
From 1.5 to six feet deep. This zone supports little emergent veg etation, but may support submerged or floating vegetation. This zone can be further broken down into forebay, micropool and deepwater channels.

Low marsh zone
Ranges from 18 to six inches below the normal pool. This area is suitable for the growth of several emergent wetland plant species.

High marsh zone
Ranges from six inches below the pool up to the normal pool. This zone will support a greater density and diversity of emergent wetland species than the low marsh zone. The high marsh zone should have a higher surface area to volume ratio than the low marsh zone.

Semi-wet zone
Are those areas above the permanent pool that are inundated on an irregular basis that can be expected to support wetland plants.

Design each stormwater wetland with the recommended proportion of treatment volumes, which have been represented as a percentage of the three basic depth zones (pool, marsh, extended detention). The allocations of treatment volume per zone are in both Tables 1 and 2.

Meet, at least, a minimum standard for the internal flow path through the stormwater wetland. This is intended to create the longest possible flow path through the stormwater wetland, and thereby increase the contact time over the surface area of the marsh. The stormwater wetland should be designed to achieve a dry weather flow path of 2:1 (length: width) or greater. A shorter flow path may be allowable for pocket wetlands.

Prepare a water budget to demonstrate that the water supply to the stormwater wetland is greater than the expected loss rate.

Provide extended detention for smaller storms (ED wetlands only). Schueler lists the following design standards for ED wetlands:

-- The volume of the extended detention should be no more than 50% of the total treatment volume.

-- The target ED detention time for this volume should be 12 to 24 hours.

-- To ensure constant detention time for all storm events the use of V-shaped or proportional weirs is encouraged.

-- Extended detention is defined here as the retention and gradual release of a fixed volume of stormwater runoff. For ED wetlands of less than 100 acres, the extended detention volume can be assumed to fill instantaneously.

-- When using a reverse slope pipe, the actual diameter of the orifice should be increased to the next greatest diameter on the standard pipe schedule, since the pipe will be equipped with a gate valve.

--The ED orifice should be well protected from clogging.

--The maximum extended detention water surface elevation should not be greater than three feet above the normal pool. The following are approximate depth ranges cited by Schueler (1992) for the various stormwater wetland designs:

Shallow marsh	0.5 to 1.5 feet
Pond/marsh	2.0 to 2.8 feet
ED Wetland	
Permanent pool	0.8 to 1.0 feet
Extended detention zone	3.3 feet
Pocket wetland	0.5 to 1.3 feet

Each stormwater wetland should be designed with a separate cell near the inlet to act as a sediment forebay. This forebay should have a capacity of at least 10% of the total treatment volume, have a direct and convenient access for cleanout, and will normally have a depth of 4 to 6 feet.

Safety ledges shall be constructed on the slopes of all new basins with a permanent pool of water deeper then two-and-one-half (2½) feet. Ledges shall be comprised of two steps, each four (4) to six (6) feet in width, one located approximately two-and-one-half (2½) feet below the permanent water surface, and the second located one (1) to one-and-one-half (1½) feet above the permanent pool.

Above ground berms or high marsh wedges should be placed at approximately 50 foot intervals, at right angles to the direction of the flow to increase the dry weather flow path within the stormwater wetland

Before the outlet, a four to six foot deep micropool, (having a capacity of at least ten percent of the total treatment volume), should be included in the design to prevent the outlet from clogging. A reverse slope pipe or a hooded, broad crested weir is the recommended outlet control. The outlet from the micropool should be located at least one foot below the normal pool surface. To prevent clogging, trash racks or hoods should be installed on the riser. To facilitate access for maintenance, the riser should be installed within the embankment. Anti-seep collars should be installed on the outlet barrel to prevent seeping losses and pipe failures.

A bottom drain pipe with an inverted elbow to prevent sediment clogging should be installed for complete draining of the stormwater wetland and for emergency purposes or routine maintenance. Both the outlet pipe and the bottom drain pipe should be fitted with adjustable valves at the outlet ends to regulate flows. Embankments and spillways should be designed in conformance with the state regulations and criteria for Dam Safety. All constructed stormwater wetlands must have an emergency spillway capable of bypassing runoff from large storms without damage to the impounding structure.

An access for maintenance, with a minimum width of 15 feet and a maximum slope of 15%, must be provided by public or private right-of-way. This access should extend to the forebay, safety bench and outflow structure and should never cross the emergency spillway unless the spillway has been designed and constructed for this purpose.

Vegetative buffers around the perimeter of the stormwater wetland are recommended for erosion control and additional sediment and nutrient removal.

Effectiveness

Table 2 shows the range of removal efficiencies for constructed stormwater wetlands. When the stormwater wetland is well planned, designed, constructed and maintained, then the reduction of the pollutant loadings should be at the high end of the reported values.

A review of the existing performance data indicates that the removal efficiencies of constructed stormwater wetlands are slightly higher than those of conventional pond systems, e.g. as wet ponds or dry extended detention ponds. Of the four designs described above, the pond/wetland system has shown the most reliable terms of overall performance. It should be noted that the performance of pocket wetlands has not been thoroughly monitored or reported. Removal efficiencies of pocket wetlands may be lower than other stormwater wetland designs, when they lack forebays. Pocket wetlands maybe prone to resuspension problems, may lack the dense vegetative cover of other stormwater wetland designs, and may lose volume to the groundwater.

Studies have also indicated that removal efficiencies of constructed stormwater wetlands decline if they are covered by ice or receive snow melt. Performance also declines during the non-growing season and during the fall when the vegetation dies back. Until vegetation is well established, pollutant removal efficiencies may be lower than expected.

However, properly designed constructed stormwater wetlands can be used to meet the Stormwater Management Standards. An off-line stormwater wetland design, for runoff quality treatment, in combination with an on-line runoff quantity control BMP may be preferred because large surges of water can damage stormwater wetlands.

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Construction

The following minimum setback requirements should apply to stormwater wetland installations:

-- Distance from a septic system leach field - 50 feet.
-- Distance from a septic system tank - 25 feet.
-- Distance from a property line - 10 feet.
-- Distance from a private well - 50 feet.

Schueler (1992) lists a seven step process for preparation of the wetland bed prior to planting:

- Prepare final pondscaping and grading plans for the stormwater wetland. At this time order wetland plant stock from aquatic nurseries.

- Once the stormwater wetland volume has been excavated, the wetland should be graded to create the major internal features (pool, aquatic bench, Deep-water channels, etc.).

- Top soil and/or wetland mulch is added to the stormwater wetland excavation.
  Since deep subsoils often lack the nutrients and organic matter to support vigorous plant growth, the addition of mulch or topsoil is important. If it is available, wetland mulch is preferable to topsoil.
  After the mulch or topsoil has been added, the stormwater wetland needs to be graded to its final elevations. All wetland features above the normal pool should be stabilized temporarily.

- After grading to final elevations, the pond drain should be closed and the pool allowed to fill. Usually nothing should be done to the stormwater wetland for six to nine months or until the next planting season. A good design recommendation is to evaluate the wetland elevations during a standing period of approximately six months. During this time the stormwater wetland can experience stormflows and inundation, so that it can be determined where the pondscaping zones are located and whether or not the final grade and microtopography will persist overtime.

- Before planting, the stormwater wetland depths should be measured to the nearest inch to confirm planting depth. The pondscape plan may be modified at this time to reflect altered depths or availability of plant stock.

- Erosion controls should be strictly applied during the standing and planting periods. All areas above the normal pool elevation should be vegetatively stabilized during the standing period, usually with hydroseeding.

- The stormwater wetland should be de-watered at least three days before planting, as a dry wetland is easier to plant than a wet one.

Once the stormwater wetland volume has been excavated, the wetland should be graded to create the major internal features (pool, aquatic bench, deep-water channels, etc.). Top soil and/or wetland mulch are added to the stormwater wetland excavation, and the stormwater wetland is graded to its final elevations. All wetland features above the normal pool should be stabilized temporarily.

During the initial planting precautions should be undertaken to prevent and prohibit animals from grazing until plant communities are well established. Such precautions could be deer fencing, muskrat trapping, planting after seasonal bird migrations or attracting birds of prey and bats to control nutria populations

<u>Operations and Maintenance</u>

Constructed stormwater wetlands require considerable routine maintenance, but do not require large, infrequent sediment removal, unlike conventional pond systems that requires relatively minor routine maintenance and expensive sediment removal at infrequent intervals.

Careful observation of the system over time is required in the first three years after construction. Within the first growing season or until it is determined that the system is established, frequent inspections will be requiired , possiblely biweekly or monthly basis. Following this , twice a year inspections are needed during both the growing and non-growing season. Data gathered during these inspections should be recorded, mapped and assessed. The following observations should be made during the inspections:

- Types and distribution of dominant wetland plants in the marsh;
- The presence and distribution of planted wetland species; the presence and distribution of volunteer wetland species; signs that volunteer species are replacing the planted wetland species;
- Percentage of unvegetated standing water (excluding the deep water cells which are not suitable for emergent plant growth);
- The maximum elevation and the vegetative condition in this zone, if the

design elevation of the normal pool is being maintained for wetlands with extended zones.

- Stability of the original depth zones and the microtopographic features;
- Accumulation of sediment in the forebay and micropool.
- Survival rate of plants in the wetland buffer.
- Regulating the sediment input to the wetland is the priority maintenance activity. The majority of sediments should be trapped and removed before they reach the wetlands either in the forebay or in a pond component. Gradual sediment accumulation in the wetland results in reduced water depths and changes in the growing conditions for the emergent plants. Furthermore, sediment removal within the wetland can destroy the wetland plant community.
- Shallow marsh and extended detention wetland designs include forebays to trap sediment before reaching the wetland. These forebays should be cleaned out every year.
- Clean outs and discharge locations should be inspected more frequently. Inspections for them could coincide with above normal or extended periods of rainfall, rather than just increasing the inspection intervals. Thus, if there are periods of drought or small infrequent events it would not necessary for and inspection.

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